



# **ASSESSMENT OF RESEARCH PROJECT SPR 371 —MAINTENANCE COST EFFECTIVENESS STUDY**

## **Final Report 371**

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16. Abstract  In 1995, the Arizona Department of Transportation (ADOT) initiated research project SPR 371, <i>Maintenance Cost Effectiveness Study</i> . That project identified the maintenance surface treatment alternatives suitable for evaluation by ADOT, developed a consensus on which alternatives to test, evaluated the performance and cost effectiveness of those treatments, and identified procurement issues that inhibit effective pavement maintenance.  As part of that study, during a period from 1999 to 2002, over 200 bituminous test sections were constructed at different locations in Arizona, including wearing courses (Phase I), surface treatments (Phase II), and sealer-rejuvenators (Phase III). While a significant effort was made to develop and construct the test sections associated with the various experimental Phases, there has been less success in monitoring these test sites and either drawing appropriate conclusions about performance and closing them out, or continuing treatments and monitoring the test sites, as was originally planned.  In this report, available documentation and data from the <i>Maintenance Cost Effectiveness Study</i> were collected and reviewed. The overall experimental phases are described, each experiment and test site is summarized, and recommendations are made for either continuing the Phase or closing it out and drawing appropriate conclusions. Overall, the potential of the findings from these various experiments to contribute to more cost effective pavement preservation practices, better specifications and construction practices, and even more cost-effective agency practices, are all reasons for better documenting these experiments and concluding them according to a rational research plan.					
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## **SI\* (MODERN METRIC) CONVERSION FACTORS**

<b>APPROXIMATE CONVERSIONS TO SI UNITS</b>					<b>APPROXIMATE CONVERSIONS FROM SI UNITS</b>				
Symbol	When You Know	Multiply By	To Find	Symbol	Symbol	When You Know	Multiply By	To Find	Symbol
<b><u>LENGTH</u></b>					<b><u>LENGTH</u></b>				
in	inches	25.4	millimeters	mm	mm	millimeters	0.039	inches	in
ft	feet	0.305	meters	m	m	meters	3.28	feet	ft
yd	yards	0.914	meters	m	m	meters	1.09	yards	yd
mi	miles	1.61	kilometers	km	km	kilometers	0.621	miles	mi
<b><u>AREA</u></b>					<b><u>AREA</u></b>				
in <sup>2</sup>	square inches	645.2	square millimeters	mm <sup>2</sup>	mm <sup>2</sup>	square millimeters	0.0016	square inches	in <sup>2</sup>
ft <sup>2</sup>	square feet	0.093	square meters	m <sup>2</sup>	m <sup>2</sup>	square meters	10.764	square feet	ft <sup>2</sup>
yd <sup>2</sup>	square yards	0.836	square meters	m <sup>2</sup>	m <sup>2</sup>	square meters	1.195	square yards	yd <sup>2</sup>
ac	acres	0.405	hectares	ha	ha	hectares	2.47	acres	ac
mi <sup>2</sup>	square miles	2.59	square kilometers	km <sup>2</sup>	km <sup>2</sup>	square kilometers	0.386	square miles	mi <sup>2</sup>
<b><u>VOLUME</u></b>					<b><u>VOLUME</u></b>				
fl oz	fluid ounces	29.57	milliliters	mL	mL	milliliters	0.034	fluid ounces	fl oz
gal	gallons	3.785	liters	L	L	liters	0.264	gallons	gal
ft <sup>3</sup>	cubic feet	0.028	cubic meters	m <sup>3</sup>	m <sup>3</sup>	cubic meters	35.315	cubic feet	ft <sup>3</sup>
yd <sup>3</sup>	cubic yards	0.765	cubic meters	m <sup>3</sup>	m <sup>3</sup>	cubic meters	1.308	cubic yards	yd <sup>3</sup>
NOTE: Volumes greater than 1000L shall be shown in m <sup>3</sup> .									
<b><u>MASS</u></b>					<b><u>MASS</u></b>				
oz	ounces	28.35	grams	g	g	grams	0.035	ounces	oz
lb	pounds	0.454	kilograms	kg	kg	kilograms	2.205	pounds	lb
T	short tons (2000lb)	0.907	megagrams (or "metric ton")	Mg (or "t")	Mg (or "t")	megagrams (or "metric ton")	1.102	short tons (2000lb)	T
<b><u>TEMPERATURE (exact)</u></b>					<b><u>TEMPERATURE (exact)</u></b>				
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celsius temperature	°C	°C	Celsius temperature	1.8C + 32	Fahrenheit temperature	°F
<b><u>ILLUMINATION</u></b>					<b><u>ILLUMINATION</u></b>				
fc	foot-candles	10.76	lux	lx	lx	lux	0.0929	foot-candles	fc
fl	foot-Lamberts	3.426	candela/m <sup>2</sup>	cd/m <sup>2</sup>	cd/m <sup>2</sup>	candela/m <sup>2</sup>	0.2919	foot-Lamberts	fl
<b><u>FORCE AND PRESSURE OR STRESS</u></b>					<b><u>FORCE AND PRESSURE OR STRESS</u></b>				
lbf	poundforce	4.45	newtons	N	N	newtons	0.225	poundforce	lbf
lbf/in <sup>2</sup>	poundforce per square inch	6.89	kilopascals	kPa	kPa	kilopascals	0.145	poundforce per square inch	lbf/in <sup>2</sup>

SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380

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# EXECUTIVE SUMMARY

## INTRODUCTION

In 1995, the Arizona Department of Transportation (ADOT) initiated research project SPR 371, *Maintenance Cost Effectiveness Study*. That project identified the maintenance surface treatment alternatives suitable for evaluation by ADOT, developed a consensus on which alternatives to test, evaluated the performance and cost effectiveness of those treatments, and identified procurement issues that inhibit effective pavement maintenance.

Under SPR 371, between 1999 and 2002, over 200 bituminous test sections were constructed at different locations throughout Arizona to evaluate the performance of different types of bituminous surfaces, including wearing courses (Phase I), surface treatments (Phase II), and sealer-rejuvenators (Phase III). However, since those sections were constructed, there has only been a minimal formal effort to evaluate their performance. Furthermore, several test sites purposely included test sections that were left untreated so that with the subsequent placement of treatments the effect of treatment timing on performance could be assessed. None of these additional test sections has been constructed.

In this report, the current status of ADOT's *Maintenance Cost Effectiveness* test sites is summarized, including a discussion of the original intent of ADOT's test sections and the data that are available. This report also includes recommendations for moving forward or closing these three study phases.

## Phase I Recommendations

The Phase I experiment is designed to analyze long-term benefits of different types of bituminous wearing courses. Primary expected benefits of the treatments used in the Phase I study are likely to include one or more of the following:

- Delayed onset of environmental (block, transverse) cracking.
- Delayed onset of fatigue (alligator) cracking.
- Reduced rutting.

Secondary benefits include better functional performance characteristics, such as resistance to weathering and raveling, better surface texture, and better ride.

Such benefits might not be expected to be realized until after 10 to 15 years, so a long-term monitoring program is desirable. At the same time, the design of this experiment—in which the existing pavement surface was milled and overlays of different thicknesses were placed—may accelerate the ability to learn lessons from the Phase I experiment. There are a number of steps that need to be taken to complete this experiment. All pavements should be evaluated using an appropriate pavement condition survey methodology. Goals of this survey are to locate, evaluate, and rate key performance indicators, including cracks, weathering and raveling, rutting, and roughness. In addition to identifying current condition, results from this survey will be used to determine which sections are still in service. A data collection/interpretation plan is also needed for this Phase. This plan should include the method of data collection, frequency of data collection, proposed method of analysis, and expected results. Finally, the plan should be carried out, which should result in identifying and using improved bituminous wearing courses.

## **Phase II Recommendations**

As with the Phase I experiment, the overall approach to the successful completion of the Phase II surface treatment experiment includes the following key activities:

- Determine what sections are still in service.
- Identify what can be learned from those sections.
- Specify how best to collect and analyze the needed information.
- Carry out the plan.

There is an added urgency to the implementation of the Phase II recommendations because this project included “do nothing” sections, which were left in place to evaluate the effect of treatment timing. Because surface treatments have a typical expected life of 5 to 8 years, immediate follow-up is essential to not losing key findings from this experiment.

In part, the data collection and analysis plan should reflect the expected benefits of applying surface treatments. One such benefit is improved surface characteristics, the measurement of which was the focus of much of the early data collection efforts, such as the use of the outflow meter and the mean texture depth. Over time, however, another benefit of applying surface treatments should be the extended time (say, versus a control section) until the pavement needs additional structural treatments, such as rehabilitation and reconstruction.

As with the Phase I sections, the benefits of applying surface treatments would be measured by monitoring the following distresses as part of a pavement condition survey using both manual and automated methods: cracks, weathering and raveling, rutting, and roughness.

An initial pavement condition survey is necessary in order to determine which sections are still in service. The next step is to develop a data collection/interpretation plan for these sections. This plan will include the data collection method, the frequency of data collection, the proposed method of analysis, and the expected results. As a minimum, this should include annual visual condition surveys completed in a formal and objective manner. However, given that some of these test sections are likely reaching the end of their lives, the frequency should be determined based on site conditions.

Aspects of the analysis that need to be addressed for the Phase II experiment include the following:

- Evaluate the use of warranties.
- Identify an appropriate tool and specification for monitoring performance under a warranty.
- Evaluate the use of proprietary products.
- Evaluate the effect of chip size on performance.
- Compare polymer-modified binders to cationic rapid set (CRS), CRS-2.
- Evaluate the use of double chip seals.
- Compare the effectiveness of wearing course treatments to surface treatments.
- Evaluate the effect of treatment application timing on pavement performance.
- Evaluate the feasibility of studying the effect of multiple treatments.

Because the Phase II sections could reasonably be expected to last 5 to 8 years, ADOT must quickly make decisions about how to continue and conclude this experiment. In addition to details of the monitoring, evaluation, and analysis that must be finalized, a prompt decision about constructing additional test sections must be made after evaluating the current conditions and prospects for the Phase II sections.

### **Phase III Recommendations**

The Phase III experiment differs from the other two in that it is part of a nationwide effort rather than purely an ADOT effort. Ideally, it would be preferable for ADOT to move forward with Phase III without relying on the national support, but this independence could become complicated, especially as evaluations in the past have involved extensive laboratory and specialized equipment testing and the use of multiple subcontractors. In this instance, the following recommendations are offered:

- Identify an ADOT liaison with the Mr. Gayle King, the researcher who has been awarded a contract to monitor the national sealer/rejuvenator study.
- Determine the level of support needed by the external researcher (such as for maintaining site and section markings, providing traffic control for evaluations, and so on), and provide a reasonable level of support.
- Consider performing regular condition surveys of the SR 87 Phase III sections, if these are being done as part of the Phase I and II evaluations.
- Develop an analysis plan for the US 93 cores. That plan should address the following questions: What analysis could be done on these cores? What is hoped to be learned? Who can perform the analysis and how much will it cost? Are the results going to be integrated into the rest of the field study or do they somehow stand on their own? The answers should be used to determine whether or not to continue with this effort.

The desired outcome of this experiment for ADOT is to determine when sealers/rejuvenators provide some benefit so that guidelines for their use can be developed for local conditions. Cooperation with the national program will help to ensure that this is accomplished.

### **OVERALL RECOMMENDATIONS AND CONCLUSIONS**

Specific recommendations are previously developed and presented for each of the three phases of ADOT's *Maintenance Cost Effectiveness Study*. More general recommendations applicable to all of the test sites are summarized below.

1. Define what is meant by "failure" for each Phase so that a test section may be formally removed from the experiment under a pre-determined and objective set of rules.
2. Verify that the section identification information at each test section is still visible. Replace and update signage and markings so that the sections can be easily located.
3. Determine whether subsequent treatments should be applied to continue the study of treatment timings.

4. Use the results from ADOT's test sites to identify which treatments are most cost effective under different applications. This concept should be applied, where possible, in the analysis and reporting of both site- and Phase-specific findings.
5. Raise the profile of these experimental sections within ADOT.
6. As the findings permit, lessons learned and information about the effectiveness of the various treatments should be translated into an implementation plan. This implementation plan could take the form of an agency-specific Pavement Preservation program, which details programs for maintaining a pavement from initial construction until it needs major rehabilitation or reconstruction.
7. Implementation should include incorporating relevant findings into revised ADOT specifications, improved statewide pavement treatment practices, and updated decision tools for pavement management.
8. The partnership between industry and ADOT that was essential to the initial development of the SPR 371 research and construction of the test sites is also essential to concluding this study and implementing the findings.
9. If ADOT is interested in using high-speed filming of pavements as a means of collecting and analyzing pavement performance, an additional investment in this technology is needed.

As part of SPR 371, ADOT has made a substantial investment in the study of wearing courses and surface treatments in Arizona. In fact, SPR 371 represents the most substantial research effort on maintenance effectiveness ever undertaken at the state level. Through the well-reasoned experimental design and subsequent construction of test sites around the state, previous researchers have created the ability to advance the state of pavement preservation practice on many different fronts, from the use of warranties and proprietary treatments, to better performing and longer lasting pavement surfaces. Improvements to current practice in any one of these areas would result in substantial tangible benefits.

However, since the construction of these test sites, there has not been a concerted effort to objectively monitor their performance. The small amount of data that has been collected has not been analyzed, and what findings are currently available are anecdotal at best. Given the age of the test sites and their expected lives, there is a strong possibility that potential lessons learned from these test sites will be lost forever. ADOT is encouraged to take immediate steps to implement some or all of these recommendations in order to benefit from the existing investment.

## INTRODUCTION

As the nation's highway agencies have shifted their emphasis away from pavement rehabilitation and reconstruction and toward pavement preservation and preventive maintenance, there have been associated changes that also require attention. For example, most agencies' experiences are with "worst-first" programming, in which the pavements that receive treatments are those in the worst condition. As they shift toward a preservation mindset, in which low-cost *preventive* treatments are applied to pavements while they are still in good condition, agencies must address issues such as the following:

- Which treatments are effective at extending pavement life?
- When should preventive maintenance treatments be applied to maximize their performance benefits?
- How do preventive maintenance treatments affect performance?
- How much life extension can be expected from available treatments?

Additional concerns that might be raised include what the costs of preservation are, what the long-term savings might be, and how preservation treatments affect issues of concern to the traveling public, such as safety and noise. The agency might then consider what changes need to be made organizationally and what improvements are needed to current specifications.

ADOT has long recognized that one of the keys to a successful pavement preservation program is "knowledge;" knowledge about what treatments work in Arizona, when they should be used, and what benefits can be expected from their effective use. In 1995, ADOT initiated research project SPR 371, *Maintenance Cost Effectiveness Study*. That project identified the maintenance surface treatment alternatives suitable for evaluation by ADOT, developed a consensus on which alternatives to test, evaluated the performance and cost effectiveness of those treatments, and identified procurement issues that inhibit effective pavement maintenance.

Since 1999, over 200 bituminous test sections have been constructed at different locations in Arizona, including wearing courses (Phase I), surface treatments (Phase II), and sealer-rejuvenators (Phase III). A brief description of each of these phases of the maintenance effectiveness project follows.

### PHASE I

ADOT's traditional bituminous pavement wearing courses have been asphalt concrete friction courses (ACFC) or asphalt rubber ACFC (AR-ACFC). However, these traditional treatments often required the application of flush coats following construction to prevent future raveling. The Phase I test sections are part of the *Wearing Course Experiment*, where "wearing course" refers to a premium plant-produced hot mix such as an open-graded friction course or a Novachip treatment. These premium treatments are intended for use on Interstates and high-volume non-interstate routes. The Phase I experiment is intended to evaluate treatments that could extend the life of a new bituminous pavement surface, with a goal of obtaining 12 to 15 years of life out of these surfaces with little or no required maintenance.

## **PHASE II**

The Phase II test sections are part of the *Surface Treatment Experiment*, where “surface treatment” refers to traditional ADOT maintenance activities such as chip seals and slurry seals. These treatments are applied to lower volume bituminous-surfaced roadways and this experiment, in particular, compares state-of-the-practice (and usually proprietary) treatments to ADOT’s traditional chip seals to determine cost effectiveness. This experiment also evaluates the use of warranties.

## **PHASE III**

The Phase III test sections constitute the Sealer-Rejuvenator or *Flush Experiment*. Surface sealers and rejuvenators are treatments that are applied to inhibit oxidation in newer bituminous surfaces, to rejuvenate the surface of older bituminous-surfaced pavements, and to prevent raveling in projects that are otherwise free of deterioration. The Phase III test sections are part of a larger, national project which originally included test sites in California, Minnesota, and Michigan.

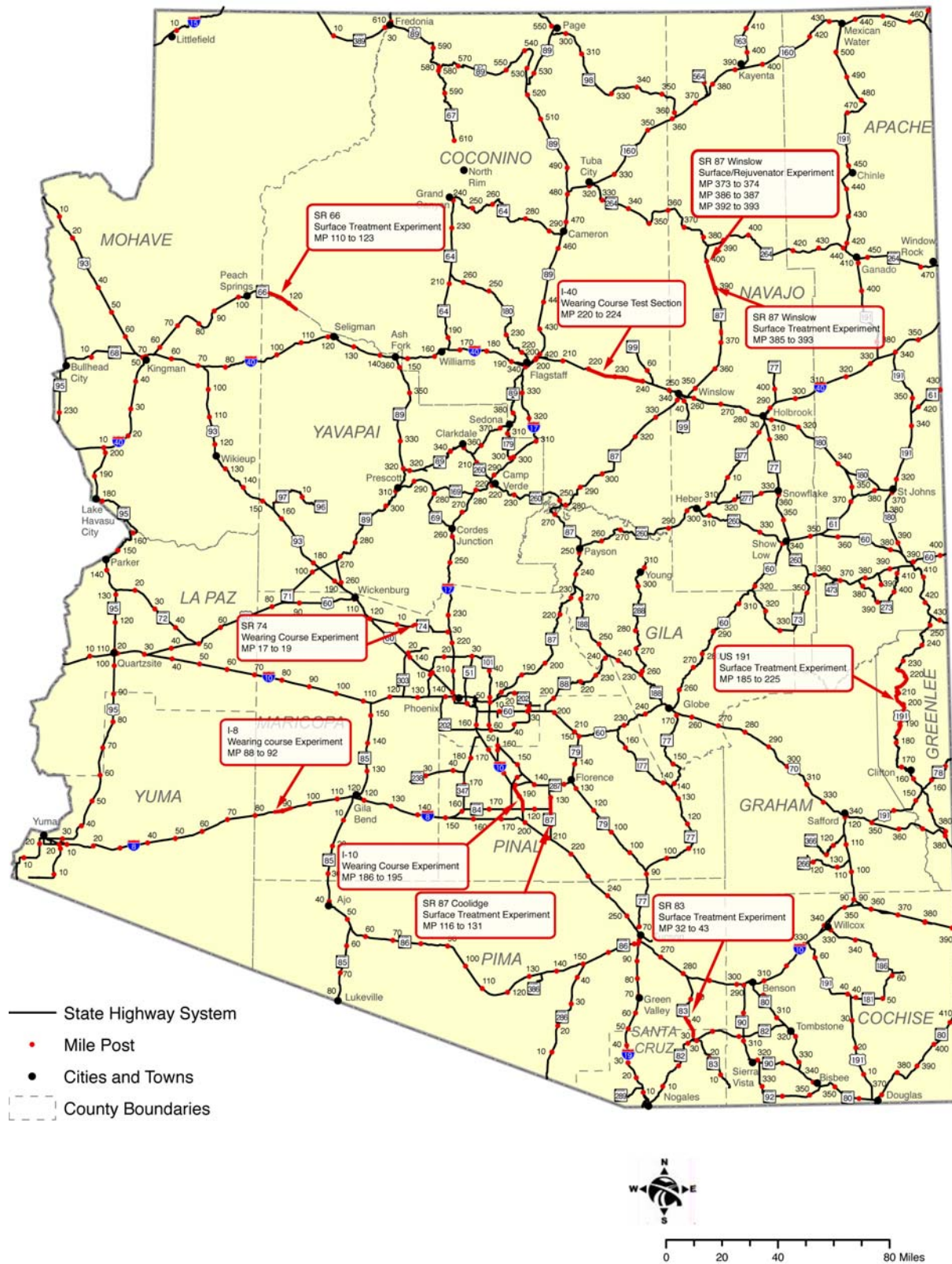
## PROJECT OBJECTIVES

As the result of a concerted effort to improve pavement performance in Arizona, from 1999 to 2001, ADOT constructed hundreds of test sections at sites around the state to study various aspects of the performance of pavement preservation treatments.

Since those sections were constructed, there has only been a minimal formal effort to evaluate their performance. Furthermore, several test sites purposely included test sections that were left untreated so that with the subsequent placement of treatments, the effect of treatment timing on performance could be assessed. None of these additional test sections has been constructed.

The purpose of this report is to summarize the current status of ADOT's *Maintenance Cost Effectiveness Study*. In broad terms, this report summarizes the original intent of ADOT's test sections, describes performance data that have been collected to date, and summarizes preliminary analysis results from the Phase I and Phase II findings. This report also includes recommendations for moving forward or closing these phases.

In addition to the above-described assessment of Phases I and II, this report provides a brief overview of the Phase III research and includes recommendations to ADOT as to how to successfully complete Phase III to meet the Department's objectives.



**FIGURE 1. LOCATION OF ADOT MAINTENANCE EFFECTIVENESS TEST SITES (ADOT 2005).**



## TEST SITE SUMMARY

There were originally eleven planned preventive maintenance test sites located throughout Arizona. The approximate locations for all of the test sections are indicated in Figure 1 for reference purposes (with the exception of the Phase III cores retrieved from US 93). The test sites are described in greater detail in the remainder of this report. As noted later, some of the original test sites have dropped out of the experiment due to site selection or construction problems.

### PHASE I TEST SITES

As indicated above, the Phase I test sections are part of the *Wearing Course Experiment*. These include the following test sites:

- I-8.
- I-10.
- I-40.
- SR 74.

The primary objective of this experiment is to analyze the long-term benefits of different surfaces and determine how to improve on current ADOT practice. As part of the original experiment, 64 test sections were constructed in the summer/fall of 1999 on I-8 and I-10, covering the five wearing course treatments shown in Table 1. Four additional sections were then constructed on long sections of I-40 without replication, and 18 sections were constructed on SR 74.

Table 1. ADOT Wearing Course Experiment treatments.

Strategy	<u>Description</u>
PEM	Permeable European Mixture (PEM) developed by the Georgia Department of Transportation (DOT) for application on urban freeways three lanes or more in width. The PEM is usually placed 1¼ inches thick and typically has 18% to 20% porosity.
SMA	Stone Matrix Asphalt (SMA) as developed by the Maryland DOT (9.5 mm top size) and used as a wearing course.
AR-ACFC	Asphalt Rubber-Asphalt Concrete Friction Course (AR-ACFC) is a typical wearing course used by ADOT on interstates and some non-interstate roadways. Performance should be linked to ADOT's historical data.
P-ACFC	Polymer Modified-Asphalt Concrete Friction Course (P-ACFC) is rarely used on ADOT roadways.
ACFC	Asphalt Concrete Friction Course (ACFC) is typically used as the main wearing course by ADOT until it was replaced by the AR-ACFC. Performance should be linked to ADOT's historical data.

All the treatments were designed to be  $\frac{3}{4}$  inches thick, with the exception of the PEM, which was designed for  $1\frac{1}{4}$  inches thick. Similarly, except for the AR-ACFC, all the polymer-modified treatments used the same PG 76-22 binder and were modified with either SB or SBS polymers. The PEM and SMA used both polymer modification and fibers to control asphalt drain down, while the P-ACFC only used polymer modification. While the wearing course treatments were placed on both the travel lane and the passing lane, only the travel lane is considered part of the experiment. As such, the construction plans required the passing lane to be constructed first to refine the placement process for the travel lane construction.

## Interstate 10 and Interstate 8

The 32 I-10 test sections are located between milepost (MP) 186.48 and MP 195.0 in the eastbound (EB) direction and the 32 sections on I-8 sections are between MP 88 and MP 92.5 in both the EB and westbound (WB) directions. Both of these sites are situated at an average elevation of about 1,400 ft; in 2001 ADOT reported the Annual Average Daily Traffic (AADT) for I-10 at 35,200 to 38,700 and for I-8 at 8,800 (ADOT 2006).

In order to accelerate ADOT's ability to draw conclusions about the performance of these different types of surfaces, either 1, 2, or 3 inches of the existing pavement's surface were milled off prior to placement of the treatment; the control section was milled  $2\frac{1}{2}$  inches. An overlay of 1, 2, or 3 inches was then placed prior to construction of the surface treatment. The expectation was that the timing of the occurrence of similar distresses in the sections of different structural capacity could be used to differentiate between the pavements' structural performance and their performance due to environmental factors. Also, having sections of different structural capacity could be used to explore the effects of applying treatments at different times in the structural life of the pavement.

Each treatment was placed on two sections, including the control treatment (which consists of a  $\frac{1}{2}$  inch AR-ACFC). The test variables at the I-8 test site are summarized in Table 2.

Table 2. Section variables and number of test section replicates for the I-8 test site.

Test Sections	Milling Thickness	2.5 in	1.0 in	2.0 in	3.0 in
	Overlay Thickness	2.0 in	2.0 in	2.0 in	2.0 in
	0.5-in AR-ACFC (control)	2			
	0.75-in AR-ACFC		2	2	2
	0.75-in ACFC		2	2	2
	0.75-in P-ACFC		2	2	2
	1.25-in PEM		2	2	2
	0.75-in SMA		2	2	2

Location and design information for test sections on both I-10 and I-8 are provided in Appendix A.

### Interstate 40

This test site is in the eastbound direction of I-40 in the general area from MP 223 to MP 220, at an average elevation of 5,400 ft. The 2001 AADT is reported at 14,500. This site consists of one test section of each of the following treatments:

- A “control” section, consisting of 0.63-in AR-ACFC [identified as Site No. 99-68, with the evaluation zone starting at MP 222.50].
- 0.75-in P-ACFC [identified as Site No. 99-67, with the evaluation zone starting at MP 221.55].
- 0.75-in PEM [identified as Site No. 99-66, with the evaluation zone starting at MP 221.00].
- 0.75-in SMA [identified as Site No. 99-65, with the evaluation zone starting at MP 220.50].

This site was added to the project because it provided an opportunity to construct 3,000-ft long sections rather than the 1,500-ft sections constructed on the I-8 and I-10 sites. During the planning for this test site, the PEM section was replaced with a “next generation” open-graded friction course design proposed by the National Center for Asphalt Technology (NCAT). The treatments were placed in 1999.

The travel lane and passing lane at the I-40 site had different structural sections by design. The travel lane construction consisted of milling 2 inches of the existing surface, placing 2 inches of ARAC, and then placing a wearing course. The passing lane construction consisted of milling off the existing wearing course and placing a new wearing course. Although traffic would be different for these two lanes, the concept was that this would still provide a basis for an additional performance comparison.

### **State Route 74**

This site includes 18 sections between MP 16.8 and MP 18.7 in both the EB and WB directions (between I-17 and US 60 in the Phoenix area), plus one control section. These test sections were constructed on SR 74 in April 2001 by change order, and include the following treatments:

- AR-ACFC
- P-ACFC
- Terminal blend friction course (76-22TR+)

This site is located at an average elevation of 1,500 ft and the 2001 AADT is reported as 4,500.

Some test sections were placed directly on the existing pavement, while others were placed over either a 2.0-in mill-and-overlay or a 3.5-in mill-and-overlay. The test variables at the SR 74 site are summarized in Table 3.

Table 3. Section variables and number of test section replicates for the SR 74 test site.

Test Sections	Milling Thickness	0 in	2.0 in	3.5 in
	Overlay Thickness	0 in	2.0 in	3.5 in
	No treatment (control)		1	
	0.75-in <sup>1</sup> AR-ACFC	2	2	2
	0.75-in P-ACFC	2	2	2
	0.75-in 76-22TR+ (SBS)	2	2	2

<sup>1</sup> Placed at a spread rate of 90 lbs/yd<sup>2</sup>, or nominally ¾-in thick.

A more detailed summary of the site is provided in Appendix B.

## PHASE I ANTICIPATED ANALYSIS

The intent of simulating accelerated pavement testing by reducing the structural capacity is to compare the effectiveness of the selected treatments in preventing return of the existing distress. Since these treatments are expected to have a relatively long life, creating a decreased structural section was also a means of generating performance results in a shorter period. In the experimental design, it was “hoped” that insight could also be gained regarding the effect of “timing” of the treatment placement for extension to roadways that would receive only the wearing course (i.e., no mill and fill or overlay). This is a tenuous extension at best, but would be helpful if successful.

In the original experiment, the properties that would be evaluated for the wearing course experiment included the following:

- Conformance to construction materials specifications.
- Binder characterization.
- Aggregate characterization.
- Ride quality.
- Frictional properties.
- Texture characterization.
- Structural capacity.
- Surface noise generation characteristics.
- Infiltration rates of wearing course.

## PHASE I STATUS AND AVAILABLE DATA

There are extensive construction-related data available for I-10, including:

- Mix sample test results (e.g., asphalt cement (AC) content, bulk density, Rice density, Marshall voids).
- Core test results (density, extracted gradations).
- Strategic Highway Research Program (SHRP) performance testing (field rutting, field fatigue, lab fatigue).
- Post-construction ignition furnace/voids analysis (gradations, density, Rice density, in-place voids, AC content).

Post-construction, the distress data collection consists of 35-mm filming of I-8 and I-10 by PASCO in 2000. ADOT then began to investigate a means of performing automated interpretation of the film, but this has never been completed. An additional survey of I-8 and I-10 using an automated distress identification van and digital datalogging was performed by Dr. Kelvin Wang. However, the use of this equipment was not successful, in part because the width of the logged pavement precluded the identification of the different test sections.

There does not appear to have been any additional data collected on these sections since construction, nor does there appear to be any specific post-construction performance evaluations of these pavements. However, it is possible that there are roughness data.

## **PHASE I RECOMMENDATIONS**

This experiment is designed to analyze long-term benefits of different surfaces. Such benefits might not be expected to be realized until after 10 to 15 years, so a long-term monitoring program is desirable. At the same time, the design of this experiment—in which the existing pavement surface was milled and overlays of different thicknesses were placed—may accelerate the ability to learn lessons from the Phase I experiment. The actual nature of that monitoring program is related to the types of benefits expected from the Phase I treatments and the types of measurements that must be made to record those benefits. Primary benefits of the treatments are likely to include one or more of the following:

- Delayed onset of environmental (block, transverse) cracking.
- Delayed onset of fatigue (alligator) cracking.
- Reduced rutting.

These should then translate into an extended performance period until rehabilitation is required.

Secondary benefits include better functional performance characteristics, such as resistance to weathering and raveling, better surface texture, and better ride.

There are a number of steps that need to be taken to complete this experiment. One of the first is to evaluate all pavements using an appropriate pavement condition survey methodology. Goals of this survey are to locate, evaluate, and rate key performance indicators, including cracks, weathering and raveling, rutting, and roughness. To conduct this evaluation, it is likely that a combination of manual and automated methods are required. In addition to identifying current condition, results from this survey will be used to determine which sections are still in service.

Next, a data collection/interpretation plan should be developed for these sections. This plan should include the method of data collection, frequency of data collection, proposed method of analysis, and expected results. Since this is a long-term performance experiment, it should be sufficient to carry out a series of annual condition surveys in order to characterize and differentiate test section performance.

In the long run, the available construction data should primarily serve to identify whether the sections were properly constructed, while the performance data should help to identify which wearing course strategies perform the best in Arizona conditions.

## PHASE II TEST SITES

The Phase II test sites are part of the *Surface Treatment Experiment*, which is designed primarily to evaluate chip seal treatments placed on lower volume roads. For many years, ADOT used a ½-inch top size aggregate in their conventional chip seals. In the 1970s this was changed to a 3/8-inch top size chip to reduce windshield damage and motorist complaints. ADOT's current standard chip seal binder is a CRS-2 emulsion. However, in the northern regions of the State, ADOT's standard design evolved to prevent damage from snow plow operations. That revised standard design consists of a double application treatment, in which ½-inch cover material is placed first; when the cover material cures, it is followed by a second application of asphalt binder, and then an application of a blotter sand as a second course.

The objectives of the surface treatment experiment are as follows:

- Evaluate the use of warranties on performance.
- Determine whether proprietary products can be specified in a competitive, low-bid process.
- Evaluate the effect of chip size on performance.
- Compare polymer-modified binders to CRS-2.
- Evaluate the use of double chip seals.
- Compare the effectiveness of wearing course treatments to surface treatments.
- Evaluate the effect of treatment application timing on pavement performance.

As in the *Wearing Course Experiment*, all treatments are replicated and their locations are randomly assigned within a project location. The core experiment consists of developing ¾-mile long test sections, one lane wide, on lower volume two-lane highways. The intent was to use one roadway direction for one replicate and the opposite roadway direction for the other replicate, duplicating the same basic layout at all of the project sites.

The core experimental design for this project was developed as part of the SR 66 test section preparation. At the SR 66 test site, the vendors/contractor selected the system to be tested and developed the specifications. As such, it was expected that the test sections represented the industry's best treatments for the pavement conditions. These systems and specifications were then meant to be used at the remaining project site locations. The original design consisted of 28 test sections, 16 designed and warranted by the contractor, and 12 test sections designed by ADOT. The following are the proprietary products included as part of the SR 66 core experiment:

- Paramount AC 15 5TR.\*
- Crown Asphalt CRS-2P (PG Graded).\*
- Koch CM 90.\*
- Copperstate HFE CRS-2P.\*
- Southwest Slurry Type III Slurry Seal.
- ISS Asphalt Rubber Chip.
- Koch Novachip.
- Copperstate CRS-2LM.
- Western Emulsion PASS CR.\*

\*5/8-inch chip size cover material only

The following treatments are a part of the core experiment:

- 5/8-inch cover material.
- 3/8-inch cover material.
- Double application chip seal.
- Double chip seal.
- ACFC.
- AR-ACFC.
- CRS-2.
- CRS-2P.

It should be noted that the 5/8-inch cover material is used as the reference material for binder comparison test sections, such as with the CRS-2 and CRS-2P, because it should be the least sensitive to construction quality.

In addition to the test site at SR 66, the Phase II experiment includes sections on SR 83, SR 87 (Winslow), SR 87 (Coolidge), and US 191. All of these test sections are described in greater detail below.

## **State Route 66**

This surface treatment test site is on SR 66, between MP 110.25 and MP 123.17 in the westbound direction and MP 110.75 and MP 123.17 in the eastbound direction. This is a two-lane highway with a 2000 AADT of approximately 2,200 and approximately 41,000 equivalent single-axle loads (ESALs)/year. The average elevation at this site is 4,500 ft.

The 28 test sections were constructed from August 10 to August 16, 2000, in the layout shown in Appendix C.

Some highlights of the SR 66 test site include the following:

- Vendor/contractor selected the surface treatment system and developed materials and construction specifications for the test sections.
- Construction specifications required a 2-year warranty.
- Macrotexture was used as the performance criteria and measured using an outflow meter. The warranty was based on meeting a minimum mean texture depth (MTD) following construction, and staying above that minimum for 2 years.

The test site was part of an overall 60-mile long construction project in which pavement conditions were similar. Prior to construction, participating material suppliers were required to visit the site and agree that pavement conditions throughout the test section were similar, so that differing pavement conditions for a specific test section were not later offered as an explanation for differential performance.

## **State Route 83**

This two-lane pavement was originally constructed in 1960 and the average elevation at this site is 4,895 ft. The 2001 AADT is 3,200. From June to August 2001, the 28 test sections on the Phase II test site at SR 83 were constructed between MP 33.20 and MP 43.50. While this test site was laid out similarly to SR 66, distinct highlights of this test section include the following:

- Used Paramount PG 76-22 TR+ for polymer-modified ACFC.
- Incorporated both AR-ACFC and ACFC sections with surface treatments.

A layout of this site is shown in Appendix D.

## **State Route 87 Winslow**

While the SR 66 project was advertised for bidding, an opportunity arose to place additional test sections on State Route 87 north of Winslow, Arizona. The original intent was to duplicate the 16 vendor test sections to be placed on SR 66. A change order was executed on the SR 87 project and six of the eight vendors participated. Due to cost considerations and the available budget for the project, three options used on SR 66 are not used on SR 87: AR Chip, Slurry Seal, and AR-ACFC.

Another major difference between the SR 66 test sections and the SR 87 test sections is that the SR 87 test sections were placed on a 1-year old, 2-inch overlay while the SR 66 test sections were placed over an old chip seal. Since the SR 87 test sections were placed on a recently placed overlay, it provided the additional opportunity to address the treatment timing issue. With this in mind, four test sections were left blank (i.e., no surface treatment was placed). Two of these test sections would have surface treatments placed in 5 to 7 years and the remaining two sections would be used as the control sections for those subsequently treated sections.

The 23 test sections on SR 87 are located north of Winslow between MP 393.463 and MP 385 in both the northbound and southbound directions, and were constructed in June and July 2000. This two-lane pavement had a 2000 AADT of approximately 500 and about 20,000 ESALs/year.

The final treatments placed on SR 87 are as follows:

- Crown CRS-2P (5/8-inch aggregate and PG-graded binder).
- Copperstate CRS-2LM (5/8-inch aggregate and latex modified binder).
- Novachip.
- ADOT Double Chip Seal (5/8-inch and 3/8-inch aggregate).
- ADOT Double Application (1/2-inch aggregate and blotter sand).
- Western Emulsion Pass Oil (5/8-inch aggregate).
- Paramount AC15-5TR (tire rubber modified binder).
- Navajo Western CM-90 (5/8-inch aggregate).

Two sections of each of these treatments were constructed, and there were also five sections that were left untreated. Three of the untreated sections are identified simply as “do nothing,” but the others were included in order to have untreated pavement to return to in 5 to 7 years, place a treatment, and evaluate the effect of treatment timing on pavement performance.



In 2001, the SR 87 test site was also used as a sealer/rejuvenator test site (this is Phase III of ADOT's *Maintenance Cost Effectiveness Study* experiment, discussed later). The Paramount AC15-5TR, a control section, and a portion of pavement outside the test section all received the sealer/rejuvenator treatments, opening up a new set of side-by-side comparisons. While the sealer/rejuvenator test sections are being addressed elsewhere, it is important to recognize that this test site was modified after construction to include these additional sections. The sealer/rejuvenator test sections are also significant because of the extensive testing and evaluation that has been planned at this location. Some highlights of the sealer/rejuvenator study are briefly discussed in Appendix E.

### **State Route 87 Coolidge**

The SR 87 sections in Coolidge were included to serve as a hot-weather alternative to the Winslow SR 87 site. The 2002 AADT at this site ranged from 2,700 to 6,500. Prior to construction, this pavement had two different pre-existing conditions—block cracking and rutting—which provided an opportunity to evaluate the effect of maintenance pre-treatment prior to placing the surface treatment. This was accomplished by placing a sand seal on half of the block cracked pavement and then placing the surface treatments.

Construction began in November 2002 between MP 116 and MP 131, toward the end of the paving season, and stopped for a winter shut-down shortly thereafter. During the shut-down, the pavement began rutting (Scofield 2003); the construction was cancelled and the test site was abandoned.

### **US 191**

The US 191 test site is located south of Alpine (at an approximate elevation of 7,000 ft), between MP 200.5 and MP 219.25. A second portion of the site is located between MP 181.0 and MP 185.0. The site was constructed in June and July 2001. Between these two test sections, the pavement received a standard treatment of AC15-5TR (rubberized chip seal) with precoated chips, which was placed in May 2001. Available information for this pavement from MP 225 and higher (just north of the test sections) indicates that it was originally built in 1962 with 16 inches of base material and a 2.5-inch bituminous surface, and that the most recent treatment was a 2-inch asphalt rubber wearing course constructed in 1999. In August 2000, this pavement north of the test sections was reported to exhibit 20 to 30 percent small block cracking and alligator cracking and transverse cracking at 20 to 25-ft intervals. The 2001 AADT is reported as 100 vehicles.

Key characteristics of this test site include the following:

- It is the only high elevation location (i.e., cold climate).
- The incorporation of non-treated sections allows the eventual study of the effect of treatment timing on pavement performance (by applying treatments in the future).
- The overlap of treatments allows a comparison between wearing course (Phase I) and surface treatment performance.

The portion of the test site between MP 181 and MP 185, where sections were left untreated, was overlaid in 1999.

The treatments placed at US 191 are summarized below. More construction information is provided in Appendix F.

- HF CRS-2P.
- Type III slurry seal.
- Novachip.
- ADOT double chip seal (5/8-inch and 3/8-inch aggregate).
- CRS-2P (3/8-inch aggregate).
- AR-ACFC.
- CM-90 (5/8-inch aggregate).
- AC 15-5TR.
- CRS-2P (5/8-inch aggregate).
- AR-chip seal.

## PHASE II ANTICIPATED ANALYSIS

There are a number of analyses contemplated with the surface treatment experiment. Some of these are summarized in Table 4, based on the “intentions” of the original experiment (with the SR 87 (Coolidge) and the SR 83 sites removed because of their reported failures).

Table 4. Expected analyses from the surface treatment test sites.

Treatment Comparison	SR 66	SR 87 Winslow	US 191 Alpine
Wearing course versus surface treatment	X	X	X
Proprietary versus ADOT standard treatments	X	X	X
Chip size (5/8-inch versus 3/8-inch)	X		X
Single chip versus double chip	X	X	X
Single chip versus double chip versus double application		X	
Treatment placement timing		X	X
Placed on recent overlay		X	X
CRS-2 versus CRS-2P			X

None of these analyses have been performed. It may also be possible to draw conclusions about the effectiveness of warranties by comparing SR 66 to other sites.

## PHASE II STATUS AND AVAILABLE DATA

Information about the current status of the Phase II test sites is based on discussions with current and former ADOT staff who have visited the sites. ADOT staff have also provided handwritten notes from visits made since the sites were constructed. Also, during fall 2004, a group from the industry and ADOT visited test sections at SR 66, SR 83, and US 191 to observe and review performance. The idea behind the visits with industry was that eventually there would be reports, but they would not mean nearly as much if those with vested interests had not made their own observations.

## **SR 66**

This is perhaps the best monitored of all the test sites, primarily because of the 2-year warranty specifications that called for testing prior to ultimate acceptance (see summary results in Appendix C). A film survey was performed by PASCO in 2000, although the distresses have never been summarized from that film. In preparing this report, handwritten notes were available from informal surveys performed on 1/10/01, 5/9/01, 8/29/01, and 7/2/02. These are summarized in Appendix C.

This test site is reported as having the “best performing” sections of any of the Phase II test sites. Many of these treatments are still in place, which is in itself noteworthy for treatments that are expected to last between 5 and 8 years at most.

The slurry seal sections are performing better than expected, but the cinder seal was performing equally as well and is much less expensive.

## **SR 83**

It has been reported that this site was taken out of service for reasons related to construction quality. Several construction reports are available for this site, and they describe widespread difficulties with all aspects of the construction, including binder application rates and equipment, aggregate sizes, cleanliness, application rate, moisture content, overlaps and treatment application widths, and so on. While there may still be some test sections in service, any review of these sections should be performed in conjunction with available construction records and an understanding of the construction problems associated with each treatment.

## **SR 87 Winslow**

This site was damaged by snow plows scraping off some off the surfacings during the first winter following construction. However, other than this initial loss of material, the sections are believed to still be in service.

## **SR 87 Coolidge**

The rutting on this site is reported to have returned shortly after treatment construction, resulting in the entire site being taken out of the experiment.

## **US 191**

No performance information on the US 191 test sites is available. Anecdotally, it was reported that work at this site highlighted the importance of placing greater emphasis on identifying the need for, and placing of, localized pre-construction repairs and on placing pavement preservation treatments earlier in the life of a pavement.

## **PHASE II RECOMMENDATIONS**

As with the Phase I experiment, the overall approach to the successful completion of the surface treatment experiment includes the following key activities:

- Determine what sections are still in service.
- Identify what can be learned from those sections.

- Specify how best to collect and analyze the needed information.
- Carry out the plan.

There is an added urgency to the implementation of the Phase II recommendations because this project included “do nothing” sections which were left in place to evaluate the effect of treatment timing. Furthermore, because surface treatments have a typical expected life of 5 to 8 years, immediate follow-up is essential to not losing key findings from this experiment.

In part, the data collection and analysis plan should reflect the expected benefits of applying surface treatments. One such benefit is improved surface characteristics, the measurement of which was the focus of much of the early data collection efforts, such as the use of the outflow meter and the mean texture depth. Over time, however, another benefit of applying surface treatments should be the extended time (say, versus a control section) until the pavement needs additional structural treatments, such as rehabilitation and reconstruction.

As with the Phase I sections, the benefits of applying surface treatments would be measured by monitoring the following distresses as part of a pavement condition survey using both manual and automated methods: cracks, weathering and raveling, rutting, and roughness.

An initial pavement condition survey is necessary in order to determine which sections are still in service. Preliminary indications are that the SR 83 and SR 87 sites failed shortly after construction and should not be considered further.

The next step is to develop a data collection/interpretation plan for these sections. This plan will include the data collection method, the frequency of data collection, the proposed method of analysis, and expected results. As a minimum, this should include annual visual condition surveys completed in a formal and objective manner. However, given that some of these test sections are likely reaching the end of their lives, the frequency should be determined based on site conditions.

Aspects of the analysis that need to be addressed for the Phase II experiment include the following:

- Evaluate the use of warranties.

There is a debate within the pavement preservation industry about whether or not warranties “work.” While this experiment will not resolve this debate, the performance of the warranted sections on SR 66 can be compared to that of non-warranted sections at the rest of the site. This test site comprised about 10 miles of an approximately 60-mile section of pavement that was treated at the same time by the same contractor. While the test sections were generally performing well at least 5 years after placement, 14 miles of the remaining 50 miles were rehabilitated within 2 years and the rest was fog sealed.

- Identify an appropriate tool and specification for monitoring performance under a warranty.

In setting up the warranty experiment, ADOT had hoped to use their newly acquired high speed texture measurement system to monitor surface treatment performance. However, it did not work, so performance monitoring was accomplished with an outflow meter and a CT Meter. While this was acceptable to monitor performance, the results are not as

useful to develop specifications based on engineering principles. ADOT should continue to evaluate available technologies that can be used to evaluate texture as part of a warranty specification.

- Evaluate the use of proprietary products.

The performance of proprietary products can also be evaluated by comparing their performance to ADOT's standard treatments. Of particular interest is whether the extra cost associated with proprietary products are offset by better performance.

### **Evaluate the effect of chip size on performance.**

With both 3/8-in and 5/8-in chip seal sections, this comparison is possible. The primary differences should be in surface texture, although there might also be differences in other conditions such as bleeding, weathering/raveling, and roughness.

- Compare polymer-modified binders to CRS-2.

There are sections that are constructed with polymer-modified binders and the more conventional CRS-2. In addition to the general performance of these different treatments, specific aspects of their differential performance to consider include bleeding, aggregate retention, and cracking.

- Evaluate the use of double chip seals.

This experiment includes sections with both single-chip and double-chip surface treatments. Double chip seals are meant to provide a better wearing surface, with better aggregate retention and a smoother and quieter ride. They also have more substance than single chip seals, and so should perform better over time. The performance of the single-chip and double-chip sections can be compared to assess these purported benefits.

- Compare the effectiveness of wearing course treatments to surface treatments.

To meet this objective, the same evaluation methods must be used for both the Phase I and Phase II test sections. Then, a definition of "effectiveness" is needed. In the short term, the effect of these different experiments can be assessed by looking at the same performance measures. Ultimately, however, "effectiveness" suggests cost effectiveness. A study of cost effectiveness requires calculating cost-benefit ratios for different treatments so that the treatment which provides the greatest improvement in condition for the lowest cost can be determined. Therefore, in addition to monitoring performance, cost information must be collected, including both initial construction costs and any subsequent differential maintenance costs. Another comparison can be made between the performance of test sections in the Phase I and Phase II experiments where AR-ACFC was used in both.

- Evaluate the effect of treatment application timing on pavement performance.

The key to being able to evaluate the effect of surface treatment timing on overall pavement performance is to have similar treatments placed at different times. Since such treatments have not been placed, first it must be determined whether the “do nothing” sections are still in service on SR 87 and US 191. Then, an engineering decision is needed as to whether something can still be learned from applying a second treatment as much as 7 years after the first one (if one were designing an experiment to evaluate treatment timing, it would probably be more “ideal” to stagger treatments 1 to 3 years rather than 7 years). If it is appropriate to continue with the evaluation of treatment timing, the next step is to select which treatments should be applied on the blank sections. If a treatment’s current performance cannot be determined, it is not a candidate for the timing experiment. Keep in mind that evaluating the effect of timing requires an appropriate measure of performance, an experiment in which all variables other than timing are held constant, and the timing of a given application is varied. If feasible, ADOT should also consider keeping additional sections without treatment to further evaluate the effect of timing on performance.

- Evaluate the feasibility of studying the effect of multiple treatments.

Some sections may benefit from application of another treatment. For example, as they near the end of their original life, a portion of some of the longer test sections could receive another treatment, while leaving a portion untreated, to evaluate the impact on performance of multiple treatments.

Because the Phase II sections could reasonably be expected to last 5 to 8 years, ADOT must quickly make decisions about how to continue and conclude this experiment. In addition to details of the monitoring, evaluation, and analysis that must be finalized, a prompt decision about constructing additional test sections must be made after evaluating the current conditions and prospects for the Phase II sections.

### **PHASE III TEST SITES**

ADOT makes frequent use of what are referred to as flush coats to inhibit oxidation in newer pavements, to rejuvenate older pavements, and to prevent raveling in projects that are experiencing some latent defects. These are reported to be applied by ADOT staff during summer months, as funds are available and need to be spent.

While these products have been widely used, their effectiveness has not been validated quantitatively. The Phase III test sites, which constitute the *Sealer/Rejuvenator* study, are designed to address this lack of documented effectiveness. Specific project objectives are summarized as follows:

- Determine the cost-effectiveness of flush coats.
- Evaluate the relevant specifications and testing for procurement and acceptance of flush coat materials.
- Determine the roadway properties that can be improved through flush coat applications and the characteristics of the flush coats necessary for the improvement.

- Evaluate the change in roadway properties with time and the ability of the flush coats to modify these changes.
- Evaluate the effect of flush coat on functional pavement performance properties, such as friction, texture, and rutting.
- Evaluate the effect of flush coats on pavement distress.
- Determine threshold properties that can be used to indicate the proper timing for application of flush coats.

Arizona's two Phase III test sites are on SR 87 and US 93. While actual test sections were constructed on SR 87, no Phase III treatments have been placed on US 93; instead, cores have been taken from this pavement at 1 and 2 years after resurfacing and are being stored by the University of Texas at El Paso (UTEP) in an environmental chamber for subsequent treatment and testing. These are part of a larger experiment that includes additional sites in California (two), Michigan (subsequently removed from the experiment), and Minnesota, and is being overseen by the Federal Highway Administration and the Foundation for Pavement Preservation. ADOT's Phase III test sections include the following treatments, which are not exactly identical to the treatments applied at the sites in other states:

- Cationic slow set (CSS), CSS-1.
- Reclamite.
- Emulsified Rejuvenating Agent (ERA), ERA-1.
- ERA-25.
- PASS oil.

In Arizona's SR 87 test sections, these treatments are placed over a friction course, a dense-graded asphalt surface, and a chip seal. They were originally constructed in 2001 and have been subjected to a battery of testing protocols under the national contract. Some of the testing that has been performed includes the following:

- Friction testing (at 24 hours, 3 months, 6 months, and then annually after construction).
- Texture testing (not according to any preset schedule).
- Retrieving and evaluating cores.
- Analysis of the elastic modulus with a Portable Seismic Pavement Analyzer (PSPA).

As with the surface treatment experiment, the flush experiment was developed in conjunction with the industry in order to represent a consensus of best practice. Additional information on the Phase III experiment is summarized in Appendix G.

## **PHASE III STATUS**

Tests have been performed by a number of different agencies (including WRI and UTEP). Evaluations were conducted by an ADOT researcher. Regular progress reports were prepared for 2001, 2002, 2004, and 2005. At that time, the following recommendations were made:

- Hire an external Principal Investigator to continue the experiment.
- Include seismic testing of both the bottom and top half of cores to create an index capability.
- Consider a sanding experiment to identify the influence of sanding on friction results.

- Develop an interim report.
- Focus on test sections that have been evaluated since initial construction.
- Conduct a second application cycle for Winslow.
- Develop and implement a follow-up testing plan for the US 93 cores stored at UTEP.

With funding and technical support, the Foundation for Pavement Preservation has hired a researcher, Mr. Gayle King, to continue with the national project. It is not known what level of effort he is expending on this or what the potential outcomes are for ADOT.

### **PHASE III RECOMMENDATIONS**

The Phase III experiment differs from the other two in that it is part of a nationwide effort rather than purely an ADOT effort. Ideally, it would be preferable for ADOT to move forward with this project without relying on the national support. However, this independence could become complicated, especially as evaluations in the past have involved extensive laboratory and specialized equipment testing and the use of multiple subcontractors. In this instance, the following recommendations are offered:

- ADOT should identify someone on staff to serve as a liaison with Mr. Gayle King, the researcher who has been awarded a contract to monitor the national sealer/rejuvenator study. This will ensure that ADOT receives regular updates on the status of the experiment, from an evaluation and analysis standpoint, and continues to have input into decisions being made about this experiment.
- ADOT should identify what level of support may be needed by the external researcher (such as for maintaining site and section markings, providing traffic control for evaluations, and so on) and provide a reasonable level of support.
- ADOT should consider performing regular condition surveys of the SR 87 Phase III sections, if these are being done as part of the Phase I and II evaluations.
- An analysis plan should be considered for the US 93 cores. That plan should address the following questions: What analysis could be done on these cores? What is hoped to be learned? Who can perform the analysis and how much will it cost? Are the results going to be integrated into the rest of the field study or do they somehow stand on their own? The answers should be used to determine whether or not to continue with this effort.

The desired outcome of this experiment for ADOT is to determine when sealers/rejuvenators provide some benefit so that guidelines for their use can be developed for local conditions. Cooperation with the national program will help to ensure that this is accomplished.



## RECOMMENDATIONS AND CONCLUSIONS

Specific recommendations are previously developed and presented for each of the three phases of ADOT's *Maintenance Cost Effectiveness Study*. More general recommendations applicable to all of the test sites are summarized below.

1. Define what is meant by "failure" for each Phase, so that a test section may be formally removed from the experiment under a pre-determined and objective set of rules.
2. Visit all test sites and evaluate treatment performance. This step includes both the application of the performance measurements and the application of the failure evaluation.
3. Verify that the section identification information at each test section is still visible. Replace and update signage and markings so that the sections can be easily located.
4. The concept of cost-effectiveness is a part of the process of the selection and application of any pavement treatment. Implicit in this concept is the notion that different treatments have both different costs and provide different benefits. Findings from ADOT's test sites may well be useful to identify which treatments are most cost effective under different applications. This concept should be applied, where possible, in the analysis and reporting of both site- and Phase-specific findings. Following the completion of the preliminary evaluation identified in item 4 above, there is an opportunity to perform a preliminary cost-effectiveness analysis now. This analysis can provide an indication of which treatments are more likely to be of value to ADOT. It should also address whether the approach used at the I-8 and I-10 test sites to accelerate the availability of results is successful.
5. The profile of these experimental sections needs to be raised. One way to accomplish this is to provide regular updates to ADOT stakeholders on the various experiments until they are completed. This would include a brief review of the status of the test sites, the lessons learned to date, planned future analyses, and the impact on practice. The update should clearly present information about the effect of the findings on pavement performance and pavement life cycle costs, and should be developed and presented annually.
6. As the findings permit, the lessons learned and information about the effectiveness of the various treatments should be translated into an implementation plan. This implementation plan could take the form of an agency-specific Pavement Preservation program, which details programs for maintaining a pavement from initial construction until it needs major rehabilitation or reconstruction.
7. Implementation should include incorporating relevant findings into revised ADOT specifications, improved statewide pavement treatment practices, and updated decision tools for pavement management.

8. The partnership between the industry and ADOT that was essential to the initial development of the SPR 371 research and construction of the test sites is also essential to concluding this study and implementing the findings. In fact, it is unlikely that the findings will ever be implemented if they do not have both industry support and ADOT champions.
9. ADOT and the Federal Highway Administration (FHWA) have already invested in the development of software that could be used to analyze the films made of pavement performance at several of the test sites. In order to complete and implement this technology, an additional investment in both software development and acquiring hardware is required. If ADOT is interested in using high-speed filming of pavements as a means of collecting and analyzing pavement performance, then this additional investment should be made.

As part of SPR 371, ADOT has made a substantial investment in the study of wearing courses and surface treatments in Arizona. In fact, SPR 371 represents the most substantial research effort on maintenance effectiveness ever undertaken at the state level. Through the well-reasoned experimental design and subsequent construction of test sites around the state, previous researchers have created the ability to advance the state of pavement preservation practice on many different fronts, from the use of warranties and proprietary treatments, to better performing and longer lasting pavement surfaces. Improvements to current practice in any one of these areas would result in substantial tangible benefits.

However, since the construction of these test sites, there has not been a concerted effort to objectively monitor their performance. The small amount of data that has been collected has not been analyzed, and what findings are currently available are anecdotal at best. Given the age of the test sites and their expected lives, there is a strong possibility that potential lessons learned from these test sites will be lost forever. ADOT is encouraged to take immediate steps to implement some or all of these recommendations in order to benefit from the existing investment.

## REFERENCES

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## APPENDIX A. TEST SITE LAYOUTS FOR I-10 AND I-8 PHASE I TEST SECTIONS.

Table A-1. Layout for I-10 Phase I test sections from EB MP 186.20 to MP 190.74.

Test Section Material	Test Section Identifier	Location by MP	Mill Thickness	Overlay Thickness
AR-ACFC (3/4-in agg)	TPSS 99-1	MP 186.48 to MP 186.76	2.5 in	2.0 in
SMA (3/4-in agg)	TPSS 99-2	MP 186.76 to MP 187.05	2.5 in	2.0 in
P-ACFC (3/4-in agg)	TPSS 99-3	MP 187.05 to MP 187.33	2.5 in	2.0 in
PEM (1 1/4-in agg)	TPSS 99-4	MP 187.33 to MP 187.61	2.5 in	2.0 in
ACFC (3/4-in agg)	TPSS 99-5	MP 187.61 to MP 187.90	2.5 in	2.0 in
AR-ACFC (3/4-in agg)	TPSS 99-6	MP 187.90 to MP 188.18	2.5 in	2.0 in
ACFC (3/4-in agg)	TPSS 99-7	MP 188.18 to MP 188.47	2.5 in	2.0 in
PEM (1 1/4-in agg)	TPSS 99-8	MP 188.47 to MP 188.75	2.5 in	2.0 in
P-ACFC (3/4-in agg)	TPSS 99-9	MP 188.75 to MP 189.03	2.5 in	2.0 in
SMA (3/4-in agg)	TPSS 99-10	MP 189.03 to MP 189.32	2.5 in	2.0 in
PEM (1 1/4-in agg)	TPSS 99-11	MP 189.32 to MP 189.60	3.5 in	3.0 in
P-ACFC (3/4-in agg)	TPSS 99-12	MP 189.60 to MP 189.89	3.5 in	3.0 in
AR-ACFC (3/4-in agg)	TPSS 99-13	MP 189.89 to MP 190.17	3.5 in	3.0 in
ACFC (3/4-in agg)	TPSS 99-14	MP 190.17 to MP 190.45	3.5 in	3.0 in
SMA (3/4-in agg)	TPSS 99-15	MP 190.45 to MP 190.74	3.5 in	3.0 in
ACFC (3/4-in agg)	TPSS 99-16	MP 190.74 to MP 191.02	3.5 in	3.0 in
AR-ACFC (3/4-in agg)	TPSS 99-17	MP 191.02 to MP 191.31	3.5 in	3.0 in
SMA (3/4-in agg)	TPSS 99-18	MP 191.31 to MP 191.59	3.5 in	3.0 in
PEM (1 1/4-in agg)	TPSS 99-19	MP 191.59 to MP 191.88	3.5 in	3.0 in
P-ACFC (3/4-in agg)	TPSS 99-20	MP 191.88 to MP 192.16	3.5 in	3.0 in
ACFC (3/4-in agg)	TPSS 99-21	MP 192.16 to MP 192.44	4.5 in	4.0 in
AR-ACFC (3/4-in agg)	TPSS 99-22	MP 192.44 to MP 192.73	4.5 in	4.0 in
SMA (3/4-in agg)	TPSS 99-23	MP 192.73 to MP 193.01	4.5 in	4.0 in
P-ACFC (3/4-in agg)	TPSS 99-24	MP 193.01 to MP 193.30	4.5 in	4.0 in
PEM (1 1/4-in agg)	TPSS 99-25	MP 193.30 to MP 193.58	4.5 in	4.0 in
ACFC (3/4-in agg)	TPSS 99-26	MP 193.58 to MP 193.86	4.5 in	4.0 in
PEM (1 1/4-in agg)	TPSS 99-27	MP 193.86 to MP 194.15	4.5 in	4.0 in
AR-ACFC (3/4-in agg)	TPSS 99-28	MP 194.15 to MP 194.43	4.5 in	4.0 in
SMA (3/4-in agg)	TPSS 99-29	MP 194.43 to MP 194.72	4.5 in	4.0 in
P-ACFC (3/4-in agg)	TPSS 99-30	MP 194.72 to MP 195.00	4.5 in	4.0 in
AR-ACFC (1/2-in agg)	Control	MP 186.20 to MP 186.48	3.5 in	3.0 in
AR-ACFC (1/2-in agg)	Control	MP 195.00 to MP 195.28	3.5 in	3.0 in

Agg = aggregate or chip

Table A-2. Layout for I-8 Phase I test sections from MP 88.0 to MP 92.53 (both directions).

Test Section Surface	Test Section Identifier	Location by MP and Direction	Mill Thickness	Overlay Thickness
AR-ACFC (3/4-in agg)	TPSS 99-34	WB MP 88.00 to MP 88.56	2.0 in	1.0 in
ACFC (3/4-in agg)	TPSS 99-35	WB MP 88.56 to MP 88.84	2.0 in	1.0 in
P-ACFC (3/4-in agg)	TPSS 99-36	WB MP 88.84 to MP 89.17	2.0 in	1.0 in
PEM (1 1/4-in agg)	TPSS 99-37	WB MP 89.17 to MP 89.41	2.0 in	1.0 in
SMA (3/4-in agg)	TPSS 99-38	WB MP 89.41 to MP 89.74	2.0 in	1.0 in
AR-ACFC (3/4-in agg)	TPSS 99-39	WB MP 89.74 to MP 89.99	2.0 in	2.0 in
ACFC (3/4-in agg)	TPSS 99-40	WB MP 89.99 to MP 90.26	2.0 in	2.0 in
P-ACFC (3/4-in agg)	TPSS 99-41	WB MP 90.26 to MP 90.50	2.0 in	2.0 in
PEM (1 1/4-in agg)	TPSS 99-42	WB MP 90.50 to MP 90.83	2.0 in	2.0 in
SMA (3/4-in agg)	TPSS 99-43	WB MP 90.83 to MP 91.11	2.0 in	2.0 in
AR-ACFC (3/4-in agg)	TPSS 99-44	WB MP 91.11 to MP 91.36	3.0 in	2.0 in
ACFC (3/4-in agg)	TPSS 99-45	WB MP 91.36 to MP 91.68	3.0 in	2.0 in
P-ACFC (3/4-in agg)	TPSS 99-46	WB MP 91.68 to MP 91.98	3.0 in	2.0 in
PEM (1 1/4-in agg)	TPSS 99-47	WB MP 91.98 to MP 92.25	3.0 in	2.0 in
SMA (3/4-in agg)	TPSS 99-48	WB MP 92.25 to MP 92.53	3.0 in	2.0 in
AR-ACFC (1/2-in agg)	TPSS 99-49 (control)	Up to WB MP 88.00	2.5 in	2.0 in
AR-ACFC (1/2-in agg)	TPSS 99-50 (control)	Up to EB MP 88.00	2.5 in	2.0 in
AR-ACFC(3/4-in agg)	TPSS 99-51	EB MP 88.00 to MP 88.28	1.0 in	2.0 in
ACFC (3/4-in agg)	TPSS 99-52	EB MP 88.28 to MP 88.57	1.0 in	2.0 in
P-ACFC (3/4-in agg)	TPSS 99-53	EB MP 88.57 to MP 88.85	1.0 in	2.0 in
PEM (1 1/4-in agg)	TPSS 99-54	EB MP 88.85 to MP 89.04	1.0 in	2.0 in
SMA (3/4-in agg)	TPSS 99-55	EB MP 89.04 to MP 89.42	1.0 in	2.0 in
AR-ACFC (3/4-in agg)	TPSS 99-56	EB MP 89.42 to MP 89.72	2.0 in	2.0 in
ACFC (3/4-in agg)	TPSS 99-57	EB MP 89.72 to MP 90.00	2.0 in	2.0 in
P-ACFC(3/4-in agg)	TPSS 99-58	EB MP 90.00 to MP 90.26	2.0 in	2.0 in
PEM (1 1/4-in agg)	TPSS 99-59	EB MP 90.26 to MP 90.39	2.0 in	2.0 in
SMA (3/4-in agg)	TPSS 99-60	EB MP 90.39 to MP 90.83	2.0 in	2.0 in
AR-ACFC (3/4-in agg)	TPSS 99-61	EB MP 90.83 to MP 91.11	3.0 in	2.0 in
ACFC (3/4-in agg)	TPSS 99-62	EB MP 91.11 to MP 91.38	3.0 in	2.0 in
P-ACFC (3/4-in agg)	TPSS 99-63	EB MP 91.38 to MP 91.68	3.0 in	2.0 in
PEM (1 1/4-in agg)	TPSS 99-64	EB MP 91.68 to MP 91.97	3.0 in	2.0 in
SMA (3/4-in agg)	TPSS 99-65	EB MP 91.97 to MP 92.53	3.0 in	2.0 in

Agg = aggregate or chip

## APPENDIX B. SUMMARY OF SR 74 CONSTRUCTION DATA

Table B-1. Summary of construction data for SR 74 Phase I test sections.

Test Section Material <sup>1</sup>	Construction Date	Location by Direction and Milepost (MP) <sup>2</sup>	Original Pavement Preparation
AR-ACFC PG 64-16 CRA-1	3/14/01	EB STA 287 + 15 to STA 297 + 70	Placed directly on original surface
	3/14/01	EB STA 274 + 96 to STA 287 + 15	Placed directly on original surface
	3/28/01	WB STA 287 + 15 to STA 297 + 70 <sup>3</sup>	Placed directly on original surface
	3/28/01	WB STA 274 + 96 to STA 287 + 15 <sup>2</sup>	Placed directly on original surface
	3/28/01	WB STA 216 + 25 to STA 230 + 60	2-in mill and replace in travel lane only
	3/28/01	WB STA 230 + 60 to STA 240 + 95	3-in mill and replace in travel lane and shoulder
	3/28/01	WB STA 240 + 95 to STA 253 + 70	3-in mill and replace in travel lane and shoulder
Paramount PG 76-22 TR+	4/03/01	EB STA 263 + 00 to STA 274 + 96	Placed directly on original surface
	4/03/01	EB STA 240 + 95 to STA 251 + 50	3-in mill and replace in travel lane and shoulder
	4/03/01	EB STA 230 + 60 to STA 240 + 95	3-in mill and replace in travel lane and shoulder
	4/03/01	EB STA 222 + 50 to STA 230 + 60	2-in mill and replace in travel lane only
	4/03/01	EB STA 209 + 25 to STA 217 + 20	2-in mill and replace in travel lane only
	4/03/01	WB STA 263 + 80 to STA 274 + 96	Placed directly on original surface
P-ACFC <sup>4</sup> PG 76-22+	4/03/01	EB STA 251 + 50 to STA 263 + 00	3-in mill and replace in travel lane and shoulder
	4/03/01	EB STA 217 + 20 to STA 222 + 50	2-in mill and replace in travel lane only
	4/03/01	EB STA 203 + 50 to STA 209 + 25	2-in mill and replace in travel lane only
	4/03/01	EB STA 200 + 50 to STA 203 + 50	2-in mill and replace in travel lane only
	4/03/01	WB STA 253 + 70 to STA 263 + 80	3-in mill and replace in travel lane and shoulder

<sup>1</sup> Gradations for all sections use a 3/8-in top-size aggregate. Target spread rate for all materials is 90 lb/yd<sup>2</sup>.

<sup>2</sup> STA 234 + 00 is MP 18 and STA 181 + 10 is MP 19.

<sup>3</sup> Sections were meant to be P-ACFC, but AR-ACFC was placed by mistake.

<sup>4</sup> Start of P-ACFC in EB direction from STA 191 + 70 to STA 200 + 50 is not in test section.





## APPENDIX C. SUMMARY OF SR 66 CONSTRUCTION DATA

Table C-1. Summary of construction data for SR 66 Phase II test sections.

Test Section Material	Construction Date	Location by Direction and Milepost (MP)	Aggregate Application	Binder Application
Crown CRS-2P PG 64-28 binder	8/11/00	WB MP 112.75 to MP 113.50	5/8-in aggregate at 26 lbs/yd <sup>2</sup>	0.50 gal/yd <sup>2</sup>
	8/11/00	EB MP 120.0 to MP 120.65 (ran short)	5/8-in aggregate at 26 lbs/yd <sup>2</sup>	0.50 gal/yd <sup>2</sup>
Copperstate CRS-2 Latex-Modified PG 64-22 binder 3% polymer	8/11/00	WB MP 113.5 to MP 114.25	5/8-in aggregate at 23 lbs/yd <sup>2</sup>	0.55 gal/yd <sup>2</sup>
	8/11/00	EB MP 113.5 to MP 114.15 (ran short)	5/8-in aggregate at 26 lbs/yd <sup>2</sup>	0.55 gal/yd <sup>2</sup>
Koch Novachip PG 70-28 binder 5.1% binder in mix Spread at 78 to 80 lbs/yd <sup>2</sup>	8/24/00	WB MP 116.2 to MP 117.0	½-in top size at 65 lbs/yd <sup>2</sup> Tack at 0.19gal/yd <sup>2</sup>	
	8/24/00	WB MP 120.0 to MP 120.75	½-in top size at 65 lbs/yd <sup>2</sup> Tack at 0.19gal/yd <sup>2</sup>	
Paramount AC15-5TR (tire rubber and polymer modified) Hot Climate	8/10/00	WB MP 116.25 to MP 117.0	26 to 28 lbs/yd <sup>2</sup>	0.50 gal/yd <sup>2</sup>
	8/10/00	EB MP 112.75 to MP 113.5	26 to 28 lbs/yd <sup>2</sup>	0.50 gal/yd <sup>2</sup> Precoated chips
Type III Microsurfacing Southwest Slurry	8/16/00	WB MP 120.75 to MP 121.5	33 lbs/yd <sup>2</sup>	
	8/15/00	EB MP 117.0 to MP 117.75	33 lbs/yd <sup>2</sup>	
Pass Oil Western Emulsion	8/12/00	WB MP 117.0 to 117.75	5/8-in aggregate at 26 lbs/yd <sup>2</sup>	0.45 gal/yd <sup>2</sup>
	8/12/00	EB MP 120.65 to MP 121.5	5/8-in aggregate at 26 lbs/yd <sup>2</sup>	0.45 gal/yd <sup>2</sup>
CM-90 Navajo Western	8/11/00	WB MP 118.5 to MP 119.35	5/8-in aggregate at 23 lbs/yd <sup>2</sup>	0.47 gal/yd <sup>2</sup>
	8/11/00	EB MP 119.23 to MP 120.0	5/8-in aggregate at 24 lbs/yd <sup>2</sup>	0.45 gal/yd <sup>2</sup>
ADOT Double Application Chip and Blotter	N/A	WB MP 110.25 to MP 111.50	½-in aggregate at 28 lbs/yd <sup>2</sup> 3/8-in aggregate at 22 lbs/yd <sup>2</sup>	0.55 gal/yd <sup>2</sup> 0.47 gal/yd <sup>2</sup>
	N/A	EB MP 110.75 to MP 111.50	½-in chip at 20 lbs/yd <sup>2</sup> 3/8-in chip: rate not known	0.55 gal/yd <sup>2</sup> 0.47 gal/yd <sup>2</sup>
Double Application [Also reported as being a single ½-in aggregate]	N/A	WB MP 111.50 to MP 112.75	N/A	N/A
	N/A	EB MP 111.50 to MP 112.75	N/A	N/A
ADOT CRS-2P 3/8-in aggregate	N/A	WB MP 114.25 to MP 115.0	N/A	N/A
	N/A	EB MP 118.5 to MP 119.23	N/A	N/A
ADOT CRS-2P 5/8-in aggregate	N/A	WB MP 122.25 to MP 123.0	N/A	N/A
	N/A	EB MP 122.25 to MP 123.0	N/A	N/A

Table C-1. Summary of construction data for SR 66 Phase II test sections. (continued).

Test Section Material	Construction Date	Location by Direction and Milepost (MP)	Aggregate Application	Binder Application
ADOT AR-ACFC	4/30/01	WB MP 121.5 to MP 122.25	Tack at 0.06 to 0.08 gal/yd <sup>2</sup> . The spread rate called for in the special provisions is 59 lbs/yd <sup>2</sup> , while it should have been 90 lbs/yd <sup>2</sup> .	
	4/30/01	EB MP 114.15 to MP 115.0		
ADOT ACFC	5/01/01	WB MP 119.35 to MP 120.0	No information available	
	5/01/01	EB MP 121.5 to MP 122.25		
AR-Chip International Slurry Surfacing	8/11/01	WB MP 117.75 to MP 118.5	24 lbs/yd <sup>2</sup>	0.62 gal/yd <sup>2</sup>
	8/11/01	EB MP 117.75 to MP 118.5	24 lbs/yd <sup>2</sup>	0.62 gal/yd <sup>2</sup> Flushed with SS-1

An AR-ACFC placed in the westbound direction between MP 115.0 and MP 116.25 and in the eastbound direction between MP 115.0 and MP 116.0 in April 2001 is identified as an “exception.”

Table C-2. Pavement performance observations for SR 66 Phase II test sections.

Test Section Material	Initial Construction	January 10, 2001	May 9, 2001	August 29, 2001	July 2, 2002
Crown CRS-2P WB PG 64-28 binder  EB	Sections went down fine. Some aggregate wet and slightly dirty.	May have lost some fines. Looks good.	Lost some fines. Chip loss at centerline.	Looks okay.	Looks good. Lots of asphalt rising to the surface.
		Looks good.	Asphalt rising to the surface. Otherwise looks good.	Some bleeding. Chip loss is minor.	Asphalt rising to the surface (on verge of bleeding). Chips still there.
Copperstate CRS-2WB Latex-Modified EB	Sections went down fine.	Looks good.	Looks great.	Looks good.	Looks great.
		Looks good.	Looks great.	Looks good.	Looks great.
Koch Novachip WB PG 70-28 binder  EB	Paved 15' 6" wide.	Looks good.	Looks good.	Looks good.	Looks great.
		Looks good.	Looks good.	Looks good.	Looks great.
Paramount AC15-5TR (tire rubber and polymer modified) Hot Climate WB  EB	Variable precoating of aggregate, but adhering well. Other than color differences, looks good.	Looks good.	Asphalt rising. Otherwise looks okay. Incipient cracking.	Looks good. Asphalt rising to surface. Reflective cracking at west end of section.	Looks good. Asphalt rising to the surface.
		Looks great.	Asphalt rising to the surface. Looks okay.	Looks good.	Looks great.
Southwest Slurry Type III Microsurfacing WB  EB	Very slow process. Some construction problems.		Tight surface. Light streak both wheelpaths.	Looks okay. Tight surface has oxidized a lot.	Surface is really dense. Otherwise looks okay.
		Good.	Looks okay. Tight surface.	Looks okay. Lots of reflective cracking.	Looks good. Cracking coming through.
Western Emulsion Pass Oil WB  EB	Aggregate spread rate in question.	Good.	One failing texture depth measure at 1 year. Looks black.	Surface looks okay, but is better at the west end. Lots of reflective cracking. Surface looks black.	Still looks black. Cracking reflecting through.
			Looking rich.	Looks good.	Looks good. Really black.
Navajo Western CM-90 WB  EB	Chips appeared dirty and very wet. Rollers made one high speed pass at placement and another 1 hour later.	Centerline raveling.	Bleeding at centerline. Otherwise looks good.	Looks rich. Lousy centerline joint and bleeding at centerline. Good outflow meter readings.	Looks okay. Lots of asphalt rising to surface.
		Centerline raveling.	Looks good. Asphalt rising to surface.	Looks rich. No chip loss. Asphalt rising to surface. Good outflow meter readings.	Lots of asphalt rising to the surface (on verge of bleeding). Chips still there.

Table C-2. Pavement performance observations for SR 66 Phase II test sections (continued).

Test Section Material	Initial Construction	January 10, 2001 <sup>1</sup>	May 9, 2001 <sup>2</sup>	August 29, 2001 <sup>3</sup>	July 2, 2002 <sup>4</sup>
ADOT Double WB Application Chip and Blotter EB		Looks good.	Bleeding strip in left wheelpath (LWP).	Some strips of bleeding.	Looks good. Slight bleeding in LWP.
		Looks good.	Asphalt rising. Otherwise looks okay.	Some strips of bleeding.	Looks good. Bleeding strip in LWP.
Double Application WB EB		No sand. Looks good.	Asphalt streaks. Cracks coming through.	Looks okay.	Looks the same as EB.
		No sand. Looks good.	Some chip loss.	Looks okay.	Looks okay. Lots of cracking between MP 111.5 and MP 112.0. Most cracks are sealed. Asphalt rising in LWP.
ADOT CRS-2P WB 3/8-in chip EB		(None)	Looks okay.	Looks good.	Looks great.
		Good.	Looks good.	Looks good. Some asphalt rising to the surface.	Looks good. Asphalt rising to the surface.
ADOT CRS-2P WB 5/8-in chip EB		Minor loss of chips at centerline. Losing chips in right wheelpath	Snowplow scarring both wheelpaths. Losing chips in both wheelpaths. Asphalt rising to the surface.	Some minor bleeding. Otherwise okay. Chip loss is minor.	Looks okay. Asphalt rising to the surface.
		Losing chips in right wheelpath			
ADOT AR-ACFC WB EB			Very thin toward end of section.	Looks good.	
			(None)	Looks good.	
ADOT ACFC WB EB		(None)	(None)	Looks good.	
			Thin toward end of section.	Looks good.	
AR Chip WB International Slurry Surfacing EB	Construction went well. Precoating looked uniform.	Good.	Right wheelpath looks rich. Lots of snowplow scarring. Looks okay.	Looks good. Plows have cleaned off some chips at longitudinal construction joints at third-points. Asphalt rubbed soft and pliable.	Looks great.
			(None)		

<sup>1</sup> 1/10/01 notes by Forstie and Stroud.

<sup>2</sup> 5/09/01 notes by Forstie, Way, and Stroud.

<sup>3</sup> 8/29/01 notes by Forstie.

<sup>4</sup> 7/02/02 notes by Forstie.

Blank cells indicate no comments provided.

Table C-3. Results of outflow testing on SR 66 at approximately 1 and 2 years.

		Acceptance Testing				1 <sup>st</sup> -Year Warranty Testing				1-Year % Decrease in MTD <sup>1</sup>	2 <sup>nd</sup> -Year (23-Month) Warranty Testing				23- Month % Decrease in MTD <sup>1</sup>
	Roadway Direction	WB		EB		WB		EB			WB		EB		
	Minimum Specification Requirement	0.8	0.6	0.8	0.6	0.7	0.5	0.7	0.5		0.7	0.5	0.7	0.5	
Product	SW Slurry Type III Microsurfacing	1.14	0.78	1.14	0.57	0.99	0.55	1.11	0.61	7.9	0.93	0.18	1.07	0.70	12.3
	Western Emulsions Pass CR	1.39	1.21	1.39	1.00	1.00	0.05	1.07	0.63	25.5	1.09	0.26	1.05	0.47	23.0
	Novachip	1.23	0.78	1.33	1.10	1.19	0.95	1.27	1.14	3.9	1.17	0.87	1.31	1.14	3.1
	Crown CRS-2P	1.53	1.53	1.53	1.53	1.45	1.41	1.43	1.39	5.9	1.47	1.42	1.45	1.35	4.6
	Koch CM 90	1.51	1.43	1.52	1.43	1.40	1.17	1.39	1.27	7.9	1.45	1.40	1.40	1.21	5.9
	ISS AR-Chip	1.49	1.43	1.51	1.43	1.45	1.44	1.44	1.41	3.7	1.48	1.42	1.46	1.41	2.0
	Paramount AC-15-5TR	1.41	0.78	1.51	1.43	1.40	1.33	1.35	1.21	5.8	1.46	1.34	1.41	1.34	1.7
	Copperstate CRS 2P	1.52	1.43	1.53	1.53	1.45	1.42	1.48	1.43	3.9	1.49	1.41	1.50	1.47	2.0

<sup>1</sup> Percent decrease is calculated as an average of the WB and EB mean texture depth (MTD) at acceptance less the average of the WB and EB MTD at warranty testing divided by the acceptance test average.



## APPENDIX D. ORIGINAL SR 83 SITE LAYOUT

Table D-1. Original site layout for SR 83 Phase II test sections.

Test Section Material	Construction Date	Location by Direction and Milepost (MP)	Comments
Type III Slurry Seal Southwest	7/14/01	NB MP 33.20 to MP 33.91	36 lbs/yd <sup>2</sup> application rate
	7/14/01	SB MP 36.97 to MP 37.58	30 lbs/yd <sup>2</sup> application rate
Double Chip Seal ADOT (3/8-in aggregate over 5/8-in aggregate)		NB MP 33.91 to MP 34.52	
	7/25/01 and 7/26/01	SB MP 41.26 to MP 41.87	5/8-in aggregate at 25 lbs/yd <sup>2</sup> 3/8-in aggregate: binder rate at 0.58 to 0.64 gal/yd <sup>2</sup>
AR-ACFC		NB MP 34.52 to MP 35.14	
		SB MP 33.20 to MP 33.91	
AR-ACFC ADOT		NB MP 35.14 to MP 35.75	
		SB MP 35.75 to MP 36.36	
CRS-2P Crown (5/8-in aggregate)	6/29/01?	NB MP 35.75 to MP 36.36	Failed due to rain and replaced with AR-ACFC.
	7/26/01	SB MP 41.87 to MP 42.48	0.55 gal/yd <sup>2</sup> binder 30 lbs/yd <sup>2</sup> aggregate
AC 15-5TR Paramount (5/8-in aggregate)	6/26/01	NB MP 36.36 to MP 37.58	0.51 gal/yd <sup>2</sup> binder 37 lbs/yd <sup>2</sup> aggregate
	6/26/01	SB MP 37.58 to MP 38.20	0.48 gal/yd <sup>2</sup> binder 34 lbs/yd <sup>2</sup> aggregate
CRS-2P ADOT (3/8-in aggregate)	7/25/01	NB MP 36.97 to MP 37.58	0.48 gal/yd <sup>2</sup> binder 30 lbs/yd <sup>2</sup> aggregate
	7/25/01	SB MP 36.36 to MP 36.97	Needed blotter sand
Asphalt Rubber Chip ISS	7/14/01	NB MP 37.58 to MP 38.20	Extensive problems meeting gradation and inadequate supply of aggregate
	7/14/01	SB MP 34.52 to MP 35.14	
P-ACFC Paramount		NB MP 38.20 to MP 40.64	
		SB MP 38.20 to MP 40.64	
Novachip Koch	8/3/01	NB MP 40.64 to MP 41.26	Binder applied at 0.2 gal/yd <sup>2</sup> . Rutting and bleeding in wheelpath
	8/3/01	SB MP 42.48 to MP 43.09	Paved 15.5 ft wide
CM-90 Koch (5/8-in aggregate)	6/26/01	NB MP 41.26 to MP 41.87	0.53 gal/yd <sup>2</sup> binder 27 lbs/yd <sup>2</sup> aggregate
	7/23/01	SB MP 35.14 to MP 35.75	0.51 gal/yd <sup>2</sup>
CRS-2 ADOT (5/8-in aggregate)		NB MP 41.87 to MP 42.48	0.5 gal/yd <sup>2</sup> binder
		SB MP 33.91 to MP 34.52	26 lbs/yd <sup>2</sup> aggregate
HF CRS-2P Copperstate (5/8-in aggregate)	7/24/01	NB MP 42.48 to MP 43.09	0.55 to 0.57 gal/yd <sup>2</sup> binder, 33 lbs/yd <sup>2</sup> aggregate
		SB MP 40.64 to MP 41.26	Ran out of emulsion at STA 463 + 15 on centerline pass
Pass CR Western Emulsion (5/8-in aggregate)	7/23/01	NB MP 43.09 to MP 43.50	0.45 gal/yd <sup>2</sup>
	7/24/01	SB MP 43.09 to MP 43.50	Chips drier than normal; construction vehicles rolled chips over

Blank cells indicate no information provided.

### APPENDIX D REFERENCES

Scofield, Larry. 2001. SR 83 Construction Diary—July 13 and 14, 2001.

Scofield, Larry. 2001. SR 83 Construction Diary—June 24, July 19, 23, 24, and 25, and August 3, 2001.

Jackson, Newton. 2001. *Summary Report SR 83 Week of June 25<sup>th</sup>*.





## APPENDIX E. SUMMARY OF SR 87 (WINSLOW) CONSTRUCTION DATA

Table E-1. Summary of construction data for SR 87 (Winslow) Phase II test sections.

Test Section Material	Construction Date	Location by Direction and Milepost (MP)	Aggregate Application	Binder Application
Crown CRS-2P PG 64-28 binder	6/14/00	SB MP 392.739 to MP 393.463	5/8-in aggregate at 26 lbs/yd <sup>2</sup>	0.48 gal/yd <sup>2</sup>
	6/14/00	SB MP 391.99 to MP 392.739	5/8-in aggregate at 26 lbs/yd <sup>2</sup>	0.48 gal/yd <sup>2</sup>
Copperstate CRS-2 Latex-Modified	6/14/00	SB MP 391.251 to 391.99	5/8-in aggregate at 26 lbs/yd <sup>2</sup>	0.50 gal/yd <sup>2</sup>
Koch Novachip PG 70-28 binder	7/6/00	SB MP 390.825 to MP 391.251	1/2-in top size at 65 lbs/yd <sup>2</sup>	0.15 to 0.17 gal/yd <sup>2</sup>
	7/6/00	NB MP 390.477 to MP 391.142	1/2-in top size at 65 lbs/yd <sup>2</sup>	0.15 to 0.17 gal/yd <sup>2</sup>
No Treatment	Do Nothing	SB MP MP 390.477 to MP 390.825		
Copperstate CRS-2 Latex-Modified	6/14/00	SB MP 389.748 to 390.477	5/8-in aggregate at 26 lbs/yd <sup>2</sup>	0.50 gal/yd <sup>2</sup>
ADOT Double Chip Seal	6/15/00	SB MP 389.0 to MP 389.748	1/2-in aggregate at 26 lbs/yd <sup>2</sup>	0.50 gal/yd <sup>2</sup>
	6/15/00	SB MP 388.25 to MP 389.0	No data for 3/8-in aggregate	No data for binder rate
	6/15/00	NB MP 389.0 to MP 389.748		
	6/15/00	NB MP 389.748 to MP 390.477		
Paramount AC15-5TR (tire rubber and polymer modified) Cold Climate	6/12/00	SB MP 387.466 to MP 388.25	Aggregate (5/8-in?) at 28 lbs/yd <sup>2</sup>	0.45 gal/yd <sup>2</sup>
	6/12/00	NB MP 392.015 to MP 392.75	Aggregate (5/8-in?) at 28 lbs/yd <sup>2</sup>	0.45 gal/yd <sup>2</sup>
No Treatment	Do Nothing	SB MP 386.5 to MP 387.466		
No Treatment	Do Nothing	SB MP 385.75 to MP 386.5	Left open for timing experiment	
ADOT Double Application Chip and Blotter	6/16/00	SB MP 385.0 to MP 385.75	1/2-in aggregate at 20 lbs/yd <sup>2</sup> #4 blotter at 8 lbs/yd <sup>2</sup>	0.47 gal/yd <sup>2</sup> 0.15 gal/yd <sup>2</sup>
	6/16/00	NB MP 385.0 to MP 385.75	1/2-in aggregate at 20 lbs/yd <sup>2</sup> #4 blotter at 8 lbs/yd <sup>2</sup>	0.47 gal/yd <sup>2</sup> 0.15 gal/yd <sup>2</sup>
Western Emulsion Pass Oil	6/15/00	NB MP 392.75 to MP 393.462	5/8-in aggregate at 26 lbs/yd <sup>2</sup>	0.45 gal/yd <sup>2</sup>
	6/15/00	NB MP 391.142 to MP 392.015	5/8-in aggregate at 26 lbs/yd <sup>2</sup>	0.45 gal/yd <sup>2</sup>
Navajo Western CM-90	6/13/00	NB MP 387.227 to MP 388.25	5/8-in aggregate at 24 lbs/yd <sup>2</sup>	0.44 gal/yd <sup>2</sup>
	6/13/00	NB MP 388.25 to MP 389.0	5/8-in aggregate at 24 lbs/yd <sup>2</sup>	0.44 gal/yd <sup>2</sup>



## APPENDIX F. SUMMARY OF US 191 CONSTRUCTION DATA

Table F-1. US 191 Phase II test sections between MP 200.50 and MP 219.25.

Test Section Material and Material Supplier	Construction Date	Location by Direction and Milepost (MP)	Aggregate Application	Binder Application
HF CRS-2P Copperstate	6/25/01	NB MP 208.75 to MP 209.75	5/8-in aggregate at 29 lbs/ yd <sup>2</sup>	0.51 gal/yd <sup>2</sup>
		SB MP 208.75 to MP 209.75	5/8-in aggregate at 29 lbs/ yd <sup>2</sup>	0.45 gal/yd <sup>2</sup>
		NB MP 217.75 to MP 218.50	5/8-in aggregate at 32 lbs/ yd <sup>2</sup>	0.5 gal/yd <sup>2</sup>
		SB MP 217.75 to MP 218.50	5/8-in aggregate at 29 lbs/ yd <sup>2</sup>	0.49 gal/yd <sup>2</sup>
Type III Slurry Seal Southwest Slurry <sup>†</sup>	6/27/01 to 6/28/01	NB MP 208.00 to MP 208.75	22.7 lbs/yd <sup>2</sup>	
		SB MP 208.00 to MP 208.75	30.6 lbs/yd <sup>2</sup>	
		NB MP 214.00 to MP 214.75	32.2 lbs/yd <sup>2</sup>	
		SB MP 214.00 to MP 214.75	29.5 lbs/yd <sup>2</sup>	
Novachip Koch	6/21/01 to 6/22/01	NB MP 207.25 to MP 208.00	Not reported. Assumed similar to data provided below. Construction notes indicate problems with placement and poor quality.	
		SB MP 207.25 to MP 208.00		
		NB MP 215.50 to MP 216.25 <sup>††</sup>		
		SB MP 215.50 to MP 216.25	90 lbs/ yd <sup>2</sup>	0.2 gal/yd <sup>2</sup>
ADOT Double Chip Seal	6/29/01 to 7/02/01	NB MP 206.50 to MP 207.25	5/8-in at 29 lbs/yd <sup>2</sup> 3/8-in at 23 lbs/yd <sup>2</sup>	0.548 gal/yd <sup>2</sup> 0.501 gal/yd <sup>2</sup>
		SB MP 388.25 to MP 389.0	5/8-in at 29 lbs/yd <sup>2</sup> 3/8-in at 23 lbs/yd <sup>2</sup>	0.567 gal/yd <sup>2</sup> 0.529 gal/yd <sup>2</sup>
		NB MP 218.50 to MP 219.25	5/8-in at 29 lbs/yd <sup>2</sup> 3/8-in at 22 lbs/yd <sup>2</sup>	0.569 gal/yd <sup>2</sup> 0.495 gal/yd <sup>2</sup>
		NB MP 218.50 to MP 219.25	5/8-in at 29 lbs/yd <sup>2</sup> Not provided	0.507 gal/yd <sup>2</sup> Not provided
P-ACFC Paramount PG 64-28	6/15/01 to 6/16/01	NB MP 205.75 to MP 206.50	N/A	N/A
		SB MP 205.75 to MP 206.50	N/A	N/A
		NB MP 217.00 to MP 217.75	N/A	N/A
		SB MP 217.00 to MP 217.75	N/A	N/A
ADOT HF CRS-2P	6/25/01	NB MP 205.00 to MP 205.75	3/8-in at 27 lbs/yd <sup>2</sup>	0.462 gal/yd <sup>2</sup>
		SB MP 205.00 to MP 205.75	3/8-in at 27 lbs/yd <sup>2</sup>	0.441 gal/yd <sup>2</sup>
		NB MP 216.25 to MP 217.00	3/8-in at 27 lbs/yd <sup>2</sup>	0.475 gal/yd <sup>2</sup>
		SB MP 216.25 to MP 217.00	3/8-in at 27 lbs/yd <sup>2</sup>	0.469 gal/yd <sup>2</sup>

Table F-1. US 191 Phase II test sections between MP 200.50 and MP 219.25 (continued).

Test Section Material and Material Supplier	Construction Date	Location by Direction and Milepost (MP)	Aggregate Application	Binder Application
ADOT AR-ACFC	6/18/01	NB MP 204.25 to MP 205.00		
		SB MP 204.25 to MP 205.00		
	6/19/01	NB MP 214.75 to MP 215.50		
		SB MP 214.75 to MP 215.50		
CM-90 (5/8-in aggregate) Koch		NB MP 203.50 to MP 204.25	N/A	N/A
		SB MP 203.50 to MP 204.25	N/A	N/A
		NB MP 212.50 to MP 213.50	N/A	N/A
		SB MP 212.50 to MP 213.50	N/A	N/A
AC15-TR Paramount	6/21/01	NB MP 202.75 to MP 203.50	5/8-in aggregate at 30 lbs/yd <sup>2</sup>	0.522 gals/yd <sup>2</sup>
		SB MP 202.75 to MP 203.50	5/8-in aggregate at 28 to 29 lbs/yd <sup>2</sup>	0.52 gals/yd <sup>2</sup>
		NB MP 211.00 to MP 211.75	5/8-in aggregate at 28 lbs/yd <sup>2</sup>	0.535 gals/yd <sup>2</sup>
		SB MP 211.00 to MP 211.75	5/8-in aggregate at 28 lbs/yd <sup>2</sup> (first 200ft at 26 lbs/yd <sup>2</sup> )	0.496 gals/yd <sup>2</sup>
CRS-2P Crown	6/26/01	NB MP 202.00 to MP 202.75	5/8-in aggregate at 28 lbs/yd <sup>2</sup>	0.571 gals/yd <sup>2</sup> (1 <sup>st</sup> 560 ft at 0.68)
		SB MP 202.00 to MP 202.75 <sup>†††</sup>	5/8-in aggregate at 28 lbs/yd <sup>2</sup>	0.55 gals/yd <sup>2</sup>
		NB MP 210.25 to MP 211.00	5/8-in aggregate at 29 lbs/yd <sup>2</sup>	0.547 gals/yd <sup>2</sup> (1 <sup>st</sup> 900 ft at 0.58)
		SB MP 210.25 to MP 211.00	5/8-in aggregate chip at 28 lbs/yd <sup>2</sup>	0.506 gals/yd <sup>2</sup>
CRS-2 ADOT	6/27/01	NB MP 201.25 to MP 202.00	3/8-in aggregate at 27 lbs/yd <sup>2</sup>	0.48 gals/yd <sup>2</sup>
		SB MP 201.25 to MP 202.00	3/8-in aggregate at 27 lbs/yd <sup>2</sup>	0.444 gals/yd <sup>2</sup>
		NB MP 211.75 to MP 212.50	3/8-in aggregate at 27 lbs/yd <sup>2</sup>	0.475 gals/yd <sup>2</sup>
		SB MP 211.75 to MP 212.50	3/8-in aggregate at 27 lbs/yd <sup>2</sup>	0.446 gals/yd <sup>2</sup>

<sup>†</sup> It is reported that the SB portions of the slurry sections were not good candidates for this treatment.

<sup>††</sup> Cool mix; paver problems in placement.

<sup>†††</sup> Ran out of Crown CRS-2P: 300 ft of this section at the end was constructed with CRS-2 and 5/8-in chip. The four corners are marked with PK nails and shiners.

Table F-2. US 191 Phase II test sections between MP 181 and MP 185.

Test Section Material and Material Supplier	Construction Date	Location by Direction and Milepost (MP)	Aggregate Application	Binder Application
AR-Chip ISS	N/A	NB MP 200.50 to MP 201.25	N/A	N/A
	N/A	SB MP 200.50 to MP 201.25	N/A	N/A
	N/A	NB MP 213.25 to MP 214.00	N/A	N/A
	N/A	SB MP 213.25 to MP 214.00	N/A	N/A
Do Nothing (control)		NB MP 184.35 to MP 185.00		
		SB MP 184.35 to MP 185.00		
		NB MP 181.67 to MP 182.34		
		SB MP 181.67 to MP 182.34		
ADOT CRS-2P Future construction		NB MP 183.68 to MP 184.35		
		SB MP 183.68 to MP 184.35		
		NB MP 182.34 to MP 183.01		
		SB MP 182.34 to MP 183.01		
ADOT CRS-2P	7/2/01 to 7/3/01	NB MP 183.01 to MP 183.68	5/8" chip at 33 lbs/yd <sup>2</sup>	0.57 gals/yd <sup>2</sup>
		SB MP 183.01 to MP 183.68	5/8" chip at 28 to 30 lbs/yd <sup>2</sup>	0.514 to 0.540 gals/yd <sup>2</sup>
		NB MP 181.00 to MP 181.67	5/8" chip at 31 to 32 lbs/yd <sup>2</sup>	0.47 to 0.550 gals/yd <sup>2</sup>
		SB MP 181.00 to MP 181.67	5/8" chip at 30 to 32 lbs/yd <sup>2</sup>	0.504 to 0.566 gals/yd <sup>2</sup>

## APPENDIX F REFERENCES

Nichols Consulting Engineers. 2001. *ADOT Surface Treatment Test Sections SR 191 South of Alpine, June and July of 2001*, Reno, NV.

Scofield, Larry. 2001. SR 191 Diary—July 31 and August 1, 2001.



## **APPENDIX G. SUMMARY OF SR 87 SEALER/REJUVENATOR STUDY**

The sealer/rejuvenator test sections constructed on SR 87 are part of a nationwide study of these treatments that are spray-applied to existing bituminous surfaces to preserve the pavement surface and extend its life. This study is co-sponsored by the following groups:

- National Center for Asphalt Technology (NCAT).
- Foundation for Pavement Preservation (FP<sup>2</sup>).
- Arizona Department of Transportation (ADOT).
- Federal Highway Administration (FHWA).

As part of the study, test sections were constructed in four states, although there are currently only three states with active sections.

The following materials are being evaluated on the SR 87 Phase III test sections:

- Reclamite.
- ERA-1.
- Pass Oil.
- ERA-25.
- CSS-1.

This experiment is set up to evaluate the effect of these treatments applied to three different surface types: dense-graded asphalt, friction course, and chip seal. The effects are being evaluated through the use of a very extensive testing program and physical evaluation. The testing program is meant to be performed at the following stages in the life of a pavement:

- Pre-Construction and Design.
- Construction.
- Post-Construction.
- Monitoring.

In the original experimental design, the following tests were to be performed:

- Infiltration Testing
  - NCAT infiltration
  - Skid Abrader Outflow Meter
  - Witco Ring Test
- Friction and Texture Measurement
  - Dynamic Friction Tester
  - CT Meter
  - ROSAN

- Non-Destructive Tests (these tests are being used to determine if aging properties of the asphalt can be identified and used as a trigger to determine when it is appropriate to apply sealer/rejuvenators)
  - Nuclear Magnetic Resonance
  - Portable Seismic Pavement Analyzer
- Determination of Chemical Compatibility
  - Automated Flocculation Titrimeter
- Formation of Surface Active Agents
  - Non-aqueous Potentiometric Titration (NAPT)
- Aging Prediction and Aging Assessment Study
  - Pressure Aging Vessel
  - Dynamic Shear Rheology (DSR)
  - Infrared Functional Group Analysis (IR-FGA)
- Compositional Analysis of Sealer/Rejuvenator Products
  - NAPT, IR-FGA, and NMR
- Distress Surveys
  - Crack extent and severity
  - Rut depth

One of the goals in this experiment is to place multiple applications of the sealer/rejuvenators. That is, following 3 to 4 years of monitoring of the original application, and second application will be made to approximately half of each of the test sections, including a control test section.

## **APPENDIX G REFERENCES**

Scofield, Larry. 2001. Winslow, Arizona Pilot Sealer/Rejuvenator Study. September 18, 2001.